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COMPARISON OF MOUNT SAINT HELENS VOLCANIC ERUPTION TO A NUCLEAR--ETC(U)
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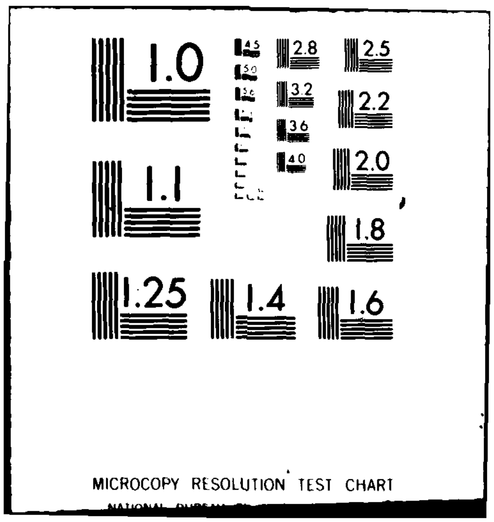
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COMPARISON OF MOUNT SAINT HELENS VOLCANIC ERUPTION TO A NUCLEAR EXPLOSION

Kenneth E. Gould
Kaman Tempo
816 State Street (P.O. Drawer QQ)
Santa Barbara, California 93102

1 January 1981

Technical Note

CONTRACT No. DNA 001-79-C-0081

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Prepared for
Director
DEFENSE NUCLEAR AGENCY
Washington, D. C. 20305

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: DASIAC TN 80-3	2. GOVT ACCESSION NO.: AD-A112 420
	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): COMPARISON OF MOUNT SAINT HELENS VOLCANIC ERUPTION TO A NUCLEAR EXPLOSION	5. TYPE OF REPORT & PERIOD COVERED: Technical Note
	6. PERFORMING ORG. REPORT NUMBER: DASIAC TN 80-3
7. AUTHOR(s): Kenneth E. Gould	8. CONTRACT OR GRANT NUMBER(s): DNA 001-79-C-0081
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Kaman Tempo, 816 State Street (P.O. Drawer QQ), Santa Barbara, California 93102	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: Subtask P99QAXDC008-09
11. CONTROLLING OFFICE NAME AND ADDRESS: Director, Defense Nuclear Agency, Washington, D.C. 20305	12. REPORT DATE: 1 January 1981
	13. NUMBER OF PAGES: 28
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS (of this report): UNCLASSIFIED
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE: N/A

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This work sponsored by the Defense Nuclea[illegible]y under RDT&E RMSS Code B337079464 P99QAXDC00809 H2590D.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Mount Saint Helens
Nuclear Explosion
Nuclear Weapons Effects
Airblast

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The phenomena and effects of airblast, ground shock, thermal radiation, cratering and ejecta, and debris cloud and deposition from the eruption of Mt. St. Helens were compared to those that would result from a nuclear explosion to determine if phenomena or effects were analogous and thus might provide useful data for military nuclear weapon effects studies. It is concluded that the phenomena are not analogous. In particular, airblast destruction was caused by clouds of ash driven by subsonic winds, rather than by a supersonic shock wave that would be the damage mechanism of a nuclear explosion. Because

20. ABSTRACT (Continued)

of the lack of analogy between the eruption and nuclear explosion phenomena, it appears questionable that any of the effects are analogous; therefore, it is unlikely that anything more of military interest can be gained from studying the effects of the eruption. However, key contacts for further information on the eruption and the associated research studies are given. The comparison of the eruption of Mt. St. Helens to the explosion of a 10- to 20-megaton nuclear weapon is misleading. Such comparisons serve no useful purpose and should be avoided.

TABLE OF CONTENTS

SECTION 1

INTRODUCTION

Eruption of steam and ash from Mt. St. Helens in the state of Washington began on 27 March 1980, following a week of local seismic activity. On 18 May 1980, a violent eruption occurred unexpectedly--approximately one billion cubic yards of ash and rock were ejected, about 1300 feet of the volcano's summit blew off, nearly 200 square miles of forest were destroyed, 61 people were killed or are missing, and ash was deposited over vast areas of the United States.

Other major eruptions have subsequently occurred, but the only additional damage has been from deposition of the large quantities of ash ejected. Six months after the first violent eruption, entry to the area within 20 miles of the volcano was still restricted. Scientists cannot forecast future volcanic activity or when such activity may cease.

Megatons of energy were released in the eruption of 18 May. This prompted interest within several Department of Defense (DOD) agencies as to whether the effects of such a large-energy release are analogous to the effects from the explosion of a large-yield nuclear weapon. If so, such data could be incorporated into nuclear weapons effects data bases, thus providing valuable new information for nuclear weapon analyses--particularly those analyses related to blast/thermal effects on forests (especially pertinent to certain tactical war scenarios). Accordingly, the Defense Nuclear Agency (DNA) authorized DASIAC, the DOD Information Analysis Center on nuclear weapons effects operated by General Electric-TEMPO, to conduct a quick-look study on the Mt. St. Helens eruptions and their effects to determine what information is being obtained or is already available and the utility of such information from the standpoint of nuclear weapon effects analyses, particularly blast/thermal analyses. A preliminary and incomplete report was issued on 9 July 1980 in which it was concluded that it was unlikely that the eruption phenomena were analogous to phenomena from a nuclear explosion. This report documents the final results of this quick-look study, based on information available as of January 1981.

In Section 2 of this report, the 18 May 1980 eruption is described, based on the concensus of scientific opinion. The volcanic eruption phenomena and effects are compared with the corresponding phenomena and effects from the explosion of a nuclear weapon in Section 3. Analysis of the available information and a discussion of the availability of data are contained in Section 4, and sources of additional information are given. Conclusions and recommendations are given in Section 5.

SECTION 2

DESCRIPTION OF THE ERUPTION

A description of the eruption phenomena and associated sequence of events is important in evaluating the validity of any analogy between the eruption phenomena and effects and nuclear weapons phenomena and effects. Both include phenomena and effects of airblast, ground shock, thermal radiation, cratering and ejecta, and debris cloud and deposition, but important differences exist between phenomena and effects from the volcano and those from a nuclear weapon. This section describes what occurred at Mt. St. Helens, based on discussions with scientists from the U.S. Geological Survey (USGS) and other agencies, plus evaluation of the available information. Data collection and analysis have been hampered by the lack of high-resolution aerial photos suitable for detailed analysis of the tree damage, the lack of other important measurement and photographic data, and the inability to examine the devastated area in detail.

Before the major eruption, USGS personnel monitoring Mt. St. Helens detected a growing bulge on the mountain's north slope. Previous geological investigations had determined that the north slope was not as structurally sound as the south slope, and geologists expected that an eruption would occur through the north slope. Nevertheless, the major eruption happened with virtually no warning and with unexpectedly devastating effects, resulting in loss of life and measurement equipment.

The eruption was apparently triggered by an earthquake with a magnitude of about 5 on the Richter Scale. It is believed the earthquake fractured the bulge and initiated a landslide, and within seconds the violent eruption occurred. Hot gases and debris vented through the north slope in two directions: vertically from the southern edge of the bulge near the summit, and laterally toward the north from the northern edge of the bulge. Such a lateral eruption blast is known to have occurred only once before and was the major factor in the unexpected widespread destruction. The dense cloud of debris shot both vertically and down the north slope at an estimated speed of 200 miles per hour, destroying everything in its path. The magma (molten rock) of the Cascade Range is thick and contains relatively large amounts of gases, releasing these gases comparatively slowly when pressure is released. Because of the relatively slow release of gases, the duration of the violent ejection of material, although unknown, was long compared to the period of ejection from a buried nuclear explosion.

A second component of the eruption was pyroclastic flows, relatively dense gas-laden flows of rock fragments. The gases appear to act like a lubricant, permitting the debris to flow relatively rapidly, much like

rushing water or a snow avalanche (speeds of up to 180 miles per hour and higher have been cited). The pyroclastic flows and the landslide poured down the north slope, generally following the lower terrain down the Toutle River Valley. The pyroclastic flows were followed by still denser pumiceous pyroclastic flows. The heat from the eruption melted enormous quantities of snow which resulted in severe mudslides down the north slope.

Rock debris, trees, and mud plunged into Spirit Lake, displacing water and forming a hummocky debris flow down the North Toutle River, which combined with the pyroclastic and mud flows to add to the flooding and destruction downstream and blocking of the Columbia River to deep-draft ships.

The volcano ejected materials for a relatively long period of time--the only tiltmeter that survived the eruption showed expansion of the mountain for 10 minutes following the initial venting before it began to deflate.

Large amounts of ash were blown to high altitudes (60,000 feet), and the hot debris created a buoyant cloud of lighter materials that rose even higher. A tremendous updraft must have been created, as evidenced by reports of pine cones and sticks raining down miles away as late as 30 minutes after the eruption, and by reports of USGS observers that a descending pyroclastic flow was sucked back up the mountain. The ash cloud expanded and drifted downwind to blanket a vast area around the volcano and far to the east. Ash on the ground was visible in the Great Plains states.

Downwind from the volcano, the eruption cloud caused an intense lightning storm described as "continuous" and starting hundreds of fires. The U.S. Forest Service (USFS) reported 30,000 acres on fire at one time. The fires were apparently extinguished by rainfall or smothered by descending ash, however.

GENERAL EFFECTS

Figure 1 is a sketch map of the area devastated by the 18 May eruption. The devastated area is highly directional, within a roughly fan-shaped area from the summit to the north between distances of 9 to 17 miles and between azimuths of about 300 and 80 degrees. Toward the northeast, the distance of complete devastation averages about 10 miles from the summit; to the northwest, the devastation distance averages about 14 miles. The area beyond 9 miles directly north of the volcano, which was not devastated, corresponds to an area sheltered behind higher peaks. The devastated region shown on the sketch map where trees are completely down, excluding the scorched area, consists of about 180 square miles, in excess of the 150 square miles usually cited in newspaper accounts. People who have viewed the devastated area almost universally comment on its distinct boundary; except for standing trees to the northwest that were scorched, trees were essentially either completely down or apparently undamaged. There was a noticeable absence of small debris on the ground. Most observers also

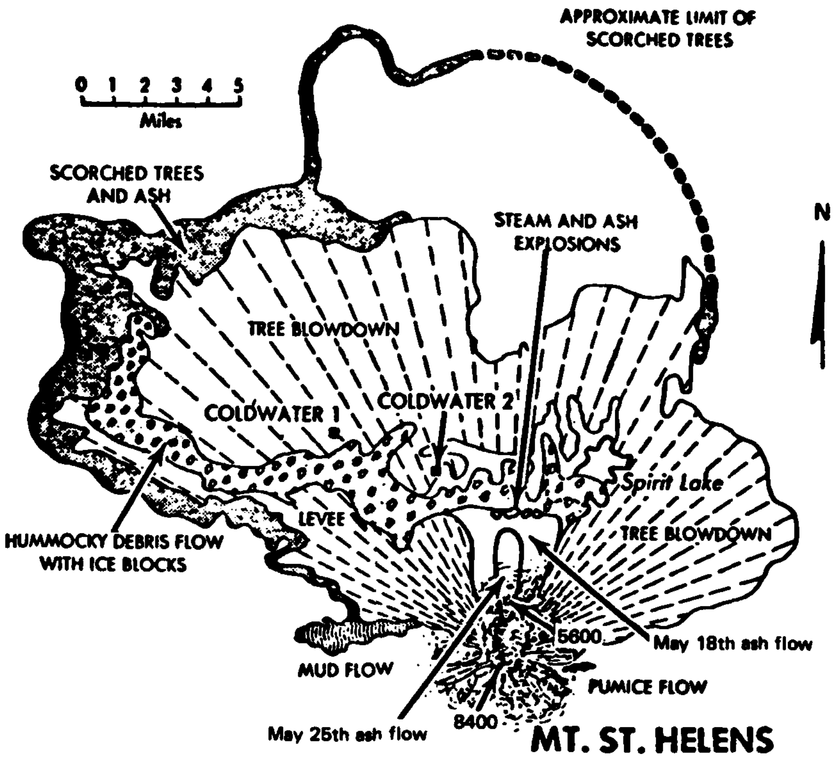

Figure 1. Drawing of devastated area effects from 18 May eruption of Mt. St. Helens. (Source: San Francisco Chronicle, 6 June 1980, p. 6; virtually identical to a USGS map from field observations through 28 May 1980)*

commented on the strong topographical effect of the trees down; whole ridges of trees were down in the same direction, but the direction varied from ridge to ridge depending on topography.

Observers also reported that, within approximately 3 to 5 miles to the north of the summit, trees and stumps were completely gone and even the earth on exposed ridges was removed down to bedrock. Reports of trees being vaporized are not credible; it is more likely that missing trees were disintegrated or moved considerable distances.

Humans in the path of the eruption cloud and pyroclastic flows died from asphyxiation by inhaling ash. Death was apparently almost

*The boundaries shown in this map differ somewhat from those of more accurate maps. However, for the purposes of this report, the differences are not significant. The more accurate maps do not illustrate the damaged area as clearly.

instantaneous; eyewitnesses of the bodies have remarked that some of the victims appeared to be "frozen" in natural, relaxed positions.

Very few manmade structures exist to the north, just beyond the area of complete devastation. This northern region is quite remote except for logging-related activities. There are no reports of any broken windows or any other blast damage outside the devastated area. In general, people close to, but outside, the devastated area did not hear or feel any blast.

SECTION 3

COMPARISON OF VOLCANIC AND NUCLEAR EXPLOSION PHENOMENA AND EFFECTS

A nuclear explosion near the ground surface produces airblast, ground shock, thermal radiation, nuclear radiations, a crater and ejecta, and a debris cloud with subsequent deposition on the ground. All of these phenomena have effects that are of military interest. Except for nuclear radiations, the violent 18 May eruption of Mt. St. Helens seemed to produce similar phenomena, which provided the rationale for this study.

In this section, each of these phenomena and its effects are analyzed to determine if there are analogies between the Mt. St. Helens eruption and a nuclear weapon explosion that are useful in a military sense. If any phenomena are analogous, the resulting eruption effects data could be directly usable in nuclear weapons effects studies. Where the phenomena are not analogous, the analysis is extended to the effects themselves to determine if some of the effects are analogous and of military use, in spite of the lack of analogy of the causative phenomena.

AIRBLAST

The extensive destruction of trees, structures, and vehicles from the 18 May eruption and the initial citing of energy yields in the range of 10 to 50 megatons nuclear equivalent created great interest within DOD because of the need for additional data comparable with that for megaton-range nuclear weapons and effects.* Unfortunately, close-in measured data on blast phenomena from the eruption are completely lacking; airblast overpressures, dynamic pressures, duration, waveforms, and dust content were not measured in the vicinity of the volcano. Therefore, any values for airblast parameters would have to be deduced from measurements at relatively long distances or from the effects produced and the known relationship of such effects to airblast parameters based on past nuclear and high-explosive tests. Nevertheless, in spite of the lack of close-in measurements, there is sufficient evidence to conclude that the eruption airblast is not analogous to airblast from a nuclear explosion. It seems conclusive that the blast effects from the eruption were caused by high-velocity winds and debris from the lateral venting and not by a shock wave, as would be the case for a nuclear explosion.

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*This range of yields was based on the effects produced (i.e., tree blowdown at 15 miles and the volume of the crater) compared with the effects of these magnitudes from a nuclear explosion.

Only a few factors indicate that a significant shock wave might have occurred from the eruption and produced significant damage:

1. One eyewitness reported seeing trees toppled before they were enveloped by the laterally venting debris. (A shock wave would propagate much faster than the debris and would precede the debris.)

2. Another eyewitness, a Navy veteran who had been indoctrinated with nuclear weapons effects films, stated that he observed a shock wave. (He was about 40 miles from the eruption.)

3. People hundreds of miles away heard the eruption and some felt it. (These phenomena can occur without an initial shock wave, however, as discussed later.)

Contrary to the factors indicating the possibility of a destructive shock wave, the following suggests that debris caused the damage instead:

1. All but one eyewitness stated that trees were standing when they were enveloped by the debris cloud, i.e., after a shock wave would have passed. This is verified by all available photographs.

2. A shock wave that would topple trees at 15 miles would have a magnitude of at least several psi at that distance and would retain shock wave characteristics considerably farther. Yet numerous eyewitnesses not far beyond the devastated area reported that they did not hear any shock wave or feel any airblast. For example, the town of Morton (population nearly 2000) is only about 25 miles north of the volcano. A shock wave of several psi at 15 miles in that direction should have produced considerable window damage and been very loud in Morton; yet the residents reportedly did not hear or feel any shock and there were no reports of any blast damage. The first indication of an eruption to these residents was the appearance of the ash cloud.

3. The tree destruction was within sharply defined azimuths, which seems more characteristic of the damage mechanism being high-velocity debris particles rather than a shock wave, which would spread out more and not show such highly directional effects.

4. There were no reports of any blast damage to people, structures, or vehicles outside the area that is completely devastated. There appears to be a sharp demarcation between severe damage and no damage, which is uncharacteristic of a shock wave.

5. Observers of the devastated area report the strong relationship of the direction of downed trees to topographical features, as if the trees were carried by a dense flow. There is visual evidence of trees "flowing" off ridges into low areas.

6. Observers report seeing downed trees with pumice embedded in one side of their trunks and their roots, indicating that the trees were toppled by a flow of high-velocity particles that continued after the trees had been uprooted.

7. Observers reported that ejecta from the initial lateral venting exists on the ground to the limits of tree devastation.

8. As described in the January 1981 issue of the National Geographic, an observer aircraft was almost directly above the volcano at a height of only about 1000 feet when the eruption began. The pilot was able to maneuver to evade the debris cloud, and the aircraft was *not damaged. Passengers and pilot* did not hear or feel any airblast. If a shock wave developed, it would have spread out and quickly enveloped the aircraft.

Jack Reed of Sandia Laboratories has collected barograph recordings from weather stations around the volcano. The time resolution of these recordings is such that pulse shapes cannot be determined (the initial "blast" shows as a single spike), but the amplitude of this pulse at the nearest station (in Toledo, Washington, about 35 miles west-northwest of the volcano) was about 4 millibars. An amplitude of 4 millibars from a shock wave is about double the threshold amplitude of breaking windows and about four times the amplitude that might produce annoying noise; yet there were no reports of window damage in Toledo, nor were there reports that any of the residents heard the eruption.

This general lack of awareness of any explosive noise relatively close to the volcano, even though the pressure amplitude in Toledo shows that overpressures must have been relatively high, indicates that the pressure pulse must have been slow-rising and lacking in the audible higher frequency components characteristic of a shock wave. (For example, 25 members of a tree-planting team only 3 miles south of the summit reported, in the National Geographic article, there was no sound from the eruption--"it was like a silent movie.")

Based on the barograph recording from Toledo, which shows an initial pressure rise, a very long-duration negative phase, and a second pressure rise about 90 minutes after the initial pressure rise, Reed has hypothesized the following sequence of events: (1) an initial slow-rising compressive pulse caused by the displacement of air by the expanding volcanic debris cloud; (2) a lengthy inflow of air as the hot debris rose to high

altitudes; and (3) a second slow-rising compressive pulse as the debris descended again and displaced the indrawn air. This hypothesis seems consistent with the available information. Reports of loud eruption noise in Seattle and other locations hundreds of miles away can be attributed to "reshocking," where the lagging components of a propagating pressure pulse "catch up" to the leading components to form a faster rising pulse with audible frequency components.

Acoustic-gravity pressure wave recordings, obtained by microbarograph stations at Boulder, Colorado, and locations farther east, reportedly resemble those from past nuclear explosions in the 10- to 20-megaton range. Dr. William Donn of the Lamont-Doherty Geophysical Observatory in Palisades, New York, believes that such waveforms could not occur in the absence of a shock wave. Conversely, Al Bedard of NOAA in Boulder, Colorado, believes an initial shock wave is not required to produce such waveforms and that any higher frequency components would have been attenuated below detectable levels at such long distances. A brief review of some of the literature on acoustic-gravity waves from nuclear explosions indicates that such waves may be produced by fireball rise and expansion as well as by shock wave. Determining whether the rising and expanding debris cloud from the volcanic eruption could produce the acoustic-gravity waveforms observed would require further analysis. However, it would appear that even without an initial shock wave, the slow-rising pressure pulse from Mt. St. Helens could "reshock," by the mechanism described above, to appear as if caused by an initial shock wave at long distances.

Tree blowdown is related to the magnitude and duration of the dynamic pressure. Dynamic pressure is proportional to the density of the air flow following the pressure front and the square of the velocity of these winds. For an ideal shock wave, a few psi peak overpressure produces peak wind velocities of about 100 miles per hour, enough for tree blowdown if of sufficient duration, e.g., from a megaton nuclear explosion. The ejected material and gases from the volcano's lateral venting had initial velocities of about 200 miles per hour, and pyroclastic flows of heavier materials with velocities up to 80 miles per hour are cited. Although these velocities are not as great as for the wind following a shock wave, the density of the air would be much greater because of the ash and other debris. Moreover, the duration of the eruption was considerable. Therefore, it seems quite likely that the dynamic-pressure effects from the debris-laden flows of the eruption were of enormous force, much greater than would have occurred from a shock wave. Such devastating and abrasive force is substantiated by observations that within about 3 to 5 miles of the venting, all trees and stumps are completely gone and even the soil has been scoured from the ridges, and that for several more miles beyond, trees are completely stripped of bark and limbs.*

*A factor of possible significance regarding missing stumps is that the Douglas Fir trees of the area have a shallow root system and uproot relatively easily.

In summary, the airblast phenomena are not analogous and any military studies on blast effects from Mt. St. Helens must recognize that the difference in the phenomena may mean that the resulting blast effects are also not analogous.

As mentioned previously, there is no known damage to vehicles or structures from blast or blast debris outside of the area that is completely devastated. The region north of Mt. St. Helens is remote with few structures near, but outside of, the devastated area. Indications are that vehicles, buildings, and other structures within the devastated area were either completely demolished or extensively damaged and that any damage by blast is masked by damage from other mechanisms--ejecta, tree debris, ashfall, mudslides, pyroclastic flows, and flooding.

The reports of blast from Mt. St. Helens toppling trees over wide areas were of considerable interest to DOD because of the concern in conducting military movements through forested areas under a nuclear weapon attack scenario. Even if the damage mechanism were not analogous to nuclear airblast, data on the tree damage might be useful in nuclear effects studies or the damaged area might provide a suitable setting for troop maneuvers or other military experiments. Any such studies or experiments, however, appear to have been forestalled by events.

Numerous snapshots and other aerial photographs of downed trees were taken, but cloud cover prevented any systematic photographic coverage of the devastated area until 19 June 1980, at which time a U-2 aircraft took high-altitude photographs. The USFS and the USAF Strategic Air Command (SAC) also took aerial photographs of the entire area. It required considerable time and effort for TEMPO to obtain copies of the high-altitude photographs that were available. Sample photographs from the State of Washington Department of Natural Resources were obtained in August but were found to be unsuitable for detailed analysis of the downed trees. At a scale of 1:24,000, tree trunks could be seen clearly under 20X magnification, but more detail would not be obtainable. The U-2 photographs and the SAC photographs were obtained in September and were also found insufficiently detailed for tree blowdown analyses.

DNA was notified that the existing photography of downed trees was not adequate for military analyses of tree blowdown and that if such photography was desired for Mt. St. Helens, a specifically designed aerial photographic mission was required. At this time, it also became apparent that interest was waning within DOD for conducting field experiments, such as troop maneuvers, in the devastated area about Mt. St. Helens. Apparently, a number of factors were responsible for this decline in interest: the delay in obtaining photographic coverage and the approaching winter, concern regarding effects of the ash on men and equipment, the fact that the area could not be certified as safe from future eruption damage, and circulation of a preliminary TEMPO report in July that pointed out the unlikelihood of the blast from Mt. St. Helens being analogous to blast from a nuclear

explosion. Accordingly, DNA decided against an aerial photographic mission to obtain low-altitude shots of portions of the devastated area that would have sufficient resolution to be useful in tree blowdown analyses.

GROUND SHOCK

Although an earthquake apparently triggered the major eruption, the ground motions from the eruption were not very energetic compared to the total energy release. A USGS scientist explained that the seismicity of the 18 May eruption itself was relatively low because the hot compressed gases were released relatively slowly from the thick magma, so that debris expansion was primarily in air and not well coupled to the ground.

Since the ground motions did not produce any known damage, it seems pointless to attempt to relate eruption ground shock to nuclear weapon ground shock. Nevertheless, numerous seismic traces were obtained from permanent and portable seismometers in the vicinity of Mt. St. Helens and at more distant locations, should such traces be of military interest.

THERMAL RADIATION

Although the volcanic eruption produced considerable thermal effects, the thermal phenomena are not analogous to those from a nuclear weapon. Nuclear weapon thermal effects occur from radiation by the intensely hot nuclear fireball (approximately one million degrees Kelvin); such radiation is restricted primarily to line-of-sight and irradiates with maximum intensity at all distances within approximately 1 second after detonation. Most of the thermal energy is delivered within a few seconds. In contrast, the Mt. St. Helens thermal effects were caused by direct contact with hot ejecta and gases, debris flows, and ash, or by lightning strikes.

Any fires initiated by the hot erupted materials and the intense lightning storm that followed the eruption are obscured by mudflows, ashfall, and rain. The USFS was preparing for large forest fires based on reports of numerous initial fire starts, but these were apparently extinguished naturally.

CRATERING AND EJECTA

The mechanisms forming the crater and ejecta are entirely different from those of a nuclear weapon burst. As described previously, the venting was both lateral and vertical and continued much longer than that from a nuclear weapon. The volcanic energy source was distributed over a large volume compared to that of a nuclear explosion. In addition, the magma expanded in the air from the relatively slow release of contained gases, providing poor coupling to the ground. No measurements of the density of the ejecta cloud or its velocity were obtained. Since the 18 May eruption, other major eruptions have occurred, with the ejection of much ash and

modification of the crater. The crater continues to change with smaller eruptions, avalanches, and filling with lava. Accurate measurements of the crater following the 18 May eruption were not obtained. Moreover, the ejected material undoubtedly has different physical characteristics and heat properties than those of the ejecta from a nuclear explosion. All of the cited difficulties and unknowns indicate that attempting to compare nuclear and the volcanic eruption cratering and ejecta phenomena and effects is fruitless.

DEBRIS CLOUD AND DEPOSITION

A University of Washington collector aircraft was airborne shortly after the first major eruption and collected gas and ash samples, although it was unsafe to venture closer than the edges of the dense ash cloud. Samples were also collected during subsequent eruptions. Whether this, and other, information from volcanic ash cloud formation, rise, diffusion, and deposition will be useful in nuclear weapons effects studies still remains to be seen. Numerous cloud and deposition samples have been collected for analysis, but any comparison with nuclear cloud fallout will be complicated by the fact that the ash has different physical characteristics as a function of time and distance. In addition, the ash from each eruption is reported to have different properties, depending on the gas-richness of the magma and other factors. Ash cloud formation and rise result from a mechanism quite different than that for a nuclear cloud; the source is not as hot as a nuclear fireball, with debris production lasting over a relatively long period of time and with initial debris velocity from the ejection process.

The volcanic ash is quite variable in size and very porous, with sharp edges. It is extremely abrasive and damaging to moving parts. One would expect that such ash would have quite different physical characteristics from the typical fallout of a nuclear weapon burst, and the ash particles shown in photographs appear very different from fallout particles from nuclear explosions that are shown in "The Effects of Nuclear Weapons." Carl Miller reports, however, in his paper, "The Contamination Behavior of Fallout-Like Particles Ejected by Volcano Irazu" (in Costa Rica), that those volcanic particles were very similar in size, shape, and density to typical nuclear weapon fallout particles.

SECTION 4

DATA AVAILABILITY AND ANALYSIS

Data regarding the Mt. St. Helens eruptions that may be of interest to DOD are described and discussed in this section. Data sources are given. The data and discussion are categorized under the appropriate nuclear effect--airblast, ground shock, thermal, crater and ejecta, and debris cloud and fallout--following a discussion of data available about the locale of the eruption. Availability of photographs is also discussed.

LOCALE INFORMATION

The nearly 200 square miles of devastated forest area are approximately 40 percent National Forest land, 40 percent privately owned (mostly by Weyerhaeuser for timber), and 20 percent State of Washington Department of Natural Resources land. The eastern portion of the devastated area is National Forest land with scattered private land areas and the western portion of the devastated area is roughly divided between private and state lands. Thus, these three major landholders have information on the characteristics of the devastated area prior to the eruption and have obtained information and conducted surveys regarding damage to their land holdings and resources. Specific locale information can be obtained by contacting the appropriate people and agencies listed at the end of this section.

There are no measurements of the meteorology in the vicinity of the volcano. National Weather Service stations at Seattle, Portland, Spokane, and numerous other locations throughout the United States are a source of meteorological data. The weather at any particular time and place can be estimated by spatial and temporal adjustment of data values from the nearby stations. Large-scale meteorological data are also available from the McIDAS system that is used for processing data from satellite observations. As discussed later, McIDAS can be used to produce images of Mt. St. Helens eruption clouds and to compute useful parameters regarding cloud characteristics and movements.

AIRBLAST

There were no close-in measurements of airblast from the 18 May eruption. The nearest measurements of air pressure changes are from weather station barographs, the closest of which is at Toledo, Washington, approximately 35 miles from the volcano. Jack Reed of Sandia Laboratories has collected copies of the barograph recordings from the weather stations in the area. The time resolution of the recordings is such that pressure waveforms and durations of the initial "pulse" cannot be determined; the "pulse" shows up as a single spike. The only positive-phase "blast"

parameter that can be obtained from barograph recordings is the peak amplitude or overpressure of the pressure rise.

Microbarograph recordings have an expanded time scale that shows waveforms to permit analysis of wave shape, frequency, duration, etc. The best such recordings from the 18 May eruption were obtained by the NOAA facility in Boulder, Colorado, the nearest operating microbarograph station to Mt. St. Helens. Copies of these recordings were furnished to DASIAC by Mr. Al Bedard but are not shown because they are not standard microbarograph recordings. The sensor includes a high-pass electronic filter so that the output must be electronically processed to remove the effects of the filtering before the actual wave shape can be obtained. Mr. Bedard presently does not plan to process the data to remove the filtering because of the considerable effort required.

Microbarograph stations at the Lamont-Doherty Geophysical Observatory in Palisades, New York, and the NOAA facility in Silver Spring, Maryland, also recorded the 18 May eruption. The waveforms are reportedly similar to those from past large-yield nuclear events; an equivalent nuclear yield of 10 to 20 megatons has been estimated. As discussed in Section 3, authorities do not agree on whether such waveforms could be obtained from a compression wave caused by expansion and buoyant rise of the eruption debris or whether a shock wave is required. The weight of the evidence is that the blast destruction was from high-velocity debris flow and not from a shock wave.

Most of the blast effects information is in the form of photographs of damage. Availability of photographs and associated data is discussed later.

GROUND SHOCK

Numerous seismograph recordings were obtained of the 18 May eruption. In addition to the seismograph station established in Vancouver, Washington at the headquarters of the USGS Mt. St. Helens operations, numerous portable seismic recorders were installed in the vicinity of the volcano. Undoubtedly, more distant stations obtained seismic recordings.

There will probably be extensive analysis of the seismic records leading up to and including the 18 May eruption.

THERMAL

Temperatures of the erupted material on the ground were obtained by the USGS for various times and locations following the 18 May eruption.

CRATER AND EJECTA

Photographs of the crater compared to the topography of Mt. St. Helens prior to the 18 May eruption are the basis for estimates of the crater

volume of material ejected and the crater dimensions. Since 18 May the crater has changed shape because of subsequent eruptions and landslides and magma rising inside the crater.

When safety permits, USGS scientists plan to measure the depths of the various layers of ash and pumice around the volcano. Since the initially ejected material has different physical characteristics from both the subsequent pyroclastic and pumice flows and from the ash cloud deposition, the depth-of-ejecta pattern and the detailed physical characteristics of the ejecta can be determined.

Velocity of the initial ejecta (as well as cloud growth) may possibly be determined from analysis of a videotape that shows the vertical venting of the 18 May eruption. (A reviewer of the tape reports that the lateral venting was obscured by a tree in the field of view.) As far as is known, this videotape is the only record that might provide a timed sequence of images--other series of photographs obtained were individual images snapped at unknown time intervals. The videotape has been incorporated into a TV documentary film, "The Mountain Erupts," which can be loaned for viewing only by KING TV in Seattle. KING TV does not have exclusive rights to the videotape other than for inclusion in its film.

DEBRIS CLOUD AND DEPOSITION

Numerous government and private agencies and individuals have collected data pertaining to the characteristics and effects of the debris clouds and the ash deposition. Dr. Lester Machta of NOAA and Dr. James Pollack of NASA are probably the two best sources of information in this area. Dr. Machta has summarized the experiments of NOAA and other agencies involved with atmospheric experiments and data collection. Dr. Pollack conducted an early workshop for Mt. St. Helens atmospheric effects and participated in a later workshop. A NASA-sponsored symposium/workshop was conducted in mid-November 1980.

All of the clouds from the major eruptions have been observed by Geosynchronous Operational Environmental Spacecraft satellites (GOES West and GOES East) and by other satellites. GOES West transmitted an image of the western United States 13 minutes after the start of the 18 May eruption, and one every 30 minutes thereafter, to the NOAA National Environmental Satellite Service. These images have been shown in Aviation Week and other publications. DASIAC has obtained prints of the cloud as observed by various satellites during 18 and 19 May. Other eruption prints can be obtained from the Application Division of the National Environmental Satellite Service of NOAA in Suitland, Maryland.

The GOES data, being digitized, can be processed via the "McIDAS" system to obtain various desired data, such as cloud dimensions, height, velocity, optical density, etc. Meteorological data from weather stations and aircraft have been incorporated into McIDAS. The images can be enhanced for better viewing. Satellite data can be processed by McIDAS at

the Federal Government Center in Suitland, Maryland, or in the Space Science and Engineering Center operated by the University of Wisconsin at Madison, Wisconsin (contact Dr. J.T. Young). There may be other McIDAS operating sites. At the University of Wisconsin, a user can either run McIDAS onsite under instruction by the staff, or the data and program can be obtained and installed on the customer's computer.

Some DOD agencies have expressed interest in the numerous lightning strikes that resulted from the volcanic cloud, a typical result from a large-yield nuclear burst cloud. A time history of the lightning discharges was obtained from an aircraft that was being used to collect cloud samples and measure air conductivity. Mr. William Cobb of NOAA, who collected the conductivity data, says that lightning discharges averaged about one every 6 seconds over a 10-minute period. Intensity data are not quantifiable, but Mr. Cobb stated that the discharges were not as energetic as those from a typical thunderstorm. The eruption cloud was heavily positively charged and the discharges were bipolar, i.e., about half discharged from positive to negative and half from negative to positive. DASIAC has Mr. Cobb's preliminary report.

There does not seem to be any coordinated and systematic program for collection and analysis of samples of the ash cloud and its deposition. Numerous agencies, such as EPA, NASA, NOAA, and other organizations have collected samples, mostly for the purpose of evaluation of health effects and ecological effects. Dr. Lester Machta of NOAA and Dr. John Pollack of NASA are probably best informed regarding atmospheric experiments and analyses.

Cloud samples were obtained relatively close to the volcano by aircraft from the following organizations:

- NASA-Ames U-2 high-altitude flights (contact Dr. James Pollack)
- University of Washington (contact Dr. Peter Hobbs)
- NOAA/ERL (contact Rudi Puesehall at the Boulder office).

The University of Washington aircraft collected samples close to the volcano during the 18 May eruption; because of its great density, the samples could only be taken on the edge of the cloud. A preliminary draft of Dr. Hobbs' observations and analyses is available. A number of other agencies have collected samples by aircraft at longer distances downwind and conducted numerous ground experiments using lidar and other techniques.

A source of relatively close-in atmospheric data near ground level is the data obtained from air samplers installed by the Environmental Protection Agency (Region IX) to measure air quality in various cities of Washington, Oregon, and Idaho. Particulate density data in mass per unit volume for various ranges of particulate sizes are available.

Battelle, LASL, EPA, USGS, and others have analyzed the ash cloud and deposition samples.

PHOTOGRAPHY

The numerous photographs of the damaged area available include the images of eruption clouds that are available through processing satellite data. The EROS data center has been designated as the repository for Federal government agency photography regarding Mt. St. Helens.

Several agencies have employed aerial photography for the purposes of mapping the damaged area or of providing detailed photoanalysis of the damage. The State of Washington Department of Natural Resources is a major source of black and white aerial photographs. Over 800 such photographs at a scale of 1:24,000 are available, and 1:12,000-scale photographs are also available that show each section of land (1-mile square) on a single 9-inch print. DASIAC has a sample of the 1:24,000-scale photos. A SAC aircraft also photographed the devastated area and DASIAC has obtained copies of the film (classified Confidential). The scale of the SAC photography appears to be about the same as the State of Washington photos. DASIAC also borrowed copies of photo-mosaics of the U-2 color-infrared photography of the area from the USFS in Houston. U-2 photographs are available from the EROS Data Center. None of the above cited photographs has the resolution necessary for detailed military studies of tree blowdown. The U.S. Corps of Engineers is reported to have obtained aerial photography, primarily of the river valleys, to assess flood damage and for evaluation of needed flood control measures. Commercial photographers have also taken aerial photographs of the devastated area, for resale and under contract to landholders.

A host of snapshots from the ground and from low-flying aircraft have been obtained during USGS and USFS surveys and other entries into the devastated area. All of these photographs are presently at the USGS Emergency Field Office in Vancouver, Washington.

Table 1 lists key individuals and offices that can be contacted regarding data and information on Mt. St. Helens.

Table 1. Key sources for Mt. St. Helens information as of January 1981.

Broad Information Sources	
Geologist for Information United States Geological Survey Vancouver, WA (206) 696-7818	Primary focal point for queries for information from the Mt. St. Helens Emergency Field Office.
Dr. John Allen Portland State University Portland, OR (503) 229-3022	Coordinate studies requiring access to the restricted area.
James Kerr Federal Emergency Management Agency Washington, D.C. (202) 653-7860	FEMA has issued a series of information bulletins on coping with eruption effects and continues to keep track of Mt. St. Helens studies and developments.
Dr. Donald Senich, Director Division for Problem-Focused Research National Science Foundation Washington, D.C. (202) 357-9666	The NSF has funded numerous research studies on Mt. St. Helens.
Airblast	
Jack Reed Sandia Laboratories Albuquerque, NM (505) 844-3042	Specialist in long-range airblast. Has collected and analyzed National Weather Service barograph recordings of the 18 May eruption.
Kenneth Gould Kaman Tempo Santa Barbara, CA (805) 963-6339	Author of this report. Experienced in explosion phenomena and effects.
Al Bedard National Oceanic and Atmospheric Administration Boulder, CO (303) 499-1000	Contact for nearest microbarograph recordings of 18 May eruption.
Dr. Lester Machta National Oceanic and Atmospheric Administration Silver Spring, MD (301) 427-7645	Contact for microbarograph recordings taken at Silver Spring NOAA facility.

(continued)

Table 1. (Continued).

Dr. William Donn Lamont Geological Laboratory Palisades, NY (914) 359-2900	Contact for microbarograph recordings taken at the Lamont Laboratory.
Photography and Imagery	
Geologist for Information United States Geological Survey Vancouver, WA (206) 696-7818	Contact for general information and for information regarding the numerous snapshots taken in the field that are presently located in Vancouver.
EROS Data Center User Services Sioux Falls, SD (605) 594-6511	All Federal agency photographs are to be sent to the EROS data center (except the classified SAC photos).
DASIAC Kaman Tempo Santa Barbara, CA (805) 963-6339 (Ken Gould)	Contact for SAC photos (classified).
Ruth Rabie State of Washington, Department of Natural Resources Seattle, WA (206) 753-5338	Source of aerial photographs.
Dr. Fredrick Weber United States Forest Service Houston, TX (713) 483-2081	Manager of program for damage assessment, from photoanalysis of U-2 photographs.
Paul Steihle, News Director KING TV Seattle, WA (206) 223-5191	Holds 3/4-inch videotape documentary of Mt. St. Helens eruption and effects that contains the only known film of the initial 18 May eruption from which a time-history of the eruption could be developed.
Roger Crystal United States Forest Service Portland, OR (503) 221-3619	Coordinator for aerial photography of Mt. St. Helens.

(continued)

Table 1. (Continued).

Mary Hughes NOAA National Environmental Satellite Service Suitland, MD (301) 763-8282	Source of imagery of eruption clouds obtained via satellites and available for analysis by the McIDAS system.
Dr. James Young University of Wisconsin Madison, WI (608) 262-6314	Additional source of imagery of eruption clouds obtained via satellite and available for analysis by the McIDAS system.
Atmospheric Effects and Ash Deposition	
Dr. Lester Machta National Oceanic and Atmospheric Administration Silver Spring, MD (301) 427-7645	Dr. Machta has summarized atmospheric-related studies on Mt. St. Helens by NOAA and other agencies.
Dr. James Pollack NASA-Ames Mountain View, CA (415) 965-5530	Dr. Pollack chaired an early symposium on Mt. St. Helens atmospheric effects.
Dr. Robert Schiffer NASA-OSTA Washington, D.C. (202) 755-8595	NASA representative at recent symposiums on Mt. St. Helens in Washington, D.C.
William Cobb National Oceanic and Atmospheric Administration Boulder, CO (303) 497-6479	Collected data and reported lightning strikes from the 18 May eruption cloud.
Dr. Allan Hirsch Environmental Protection Agency Washington, D.C. (202) 426-0803	EPA contact.
Jonathan Fruchter, et al. Battelle Memorial Institute Pacific Northwest Laboratory Richland, WA	Author of article in 5 September 1980 issue of Science on ash characteristics.

SECTION 5

CONCLUSIONS, RECOMMENDATIONS, AND COMMENTS

The major conclusion of this study is that the eruption phenomena are not analogous to nuclear explosion phenomena. In particular, the tree destruction was caused by subsonic winds heavily laden with ash, rather than by a supersonic shock wave that would be the damage mechanism of a nuclear explosion.

It appears unlikely that anything more of military interest is to be gained from studying the effects of the eruption phenomena. Photographic coverage of the devastated area in sufficient detail for tree blowdown studies does not exist. Interest in conducting troop maneuvers among the downed trees has waned and any such maneuvers could not be conducted until late spring, one year after the destructive eruption. There will be considerable reporting of scientific studies of atmospheric effects of the eruption clouds, but it seems questionable that any such studies will have direct bearing on studies of nuclear clouds and fallout.

It is unfortunate that the energy release from the 18 May eruption of Mt. St. Helens was compared to that of a nuclear weapon explosion; since the phenomena are not analogous, such comparisons are misleading. There is no yield of nuclear weapon that would cause the entire range of blast effects that resulted from the 18 May eruption of Mt. St. Helens. To illustrate this point, the long-distance microbarograph data indicated a distant pressure pulse comparable to a 10- to 20-megaton nuclear explosion. To topple virtually all trees at a distance of 15 miles, however, would require a shock wave from a nuclear explosion in excess of 100 megatons. To further illustrate, the shock wave from a 100-megaton nuclear explosion would have caused widespread destruction to the south of the volcano and some damage beyond the 15-mile limit of the devastated area. Comparisons of natural disasters to a nuclear weapon yield serve no useful purpose and should be avoided.

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